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# QUANTITATIVE PLANKTON STUDIES ON LAKE BALATON X. NOTES ON THE DISTRIBUTION OF *LEPTODORA KINDTII* FOCKE.

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In studying the distribution of the members of the lake plankton community — in both qualitative and quantitative aspects — some principles must be followed when taking the samples. Concerning to plankton animals these are: size;

rate of active locomotion;

frequency of occurrence.

Among plankton crustaceans three groups could be distinguished in this sense:

1. nauplii and metanauplii of copepods;
2. copepods of more advanced age and cladocerans excluding *Leptodora*;
3. *Leptodora*.

Although the nauplii of the copepods are rather quick in locomotion, on account of both their small size and their frequent occurrence w a t e r s a m p l e s taken from different depths are suitable for quantitative purposes.

As to the copepodits and adults of copepods as well as to most of the cladocerans more water samples are needed, because of their more effective locomotion and less frequent occurrence. Rheotaxis must be taken also in consideration.

In order to establish the population density of *Leptodora*, because of its able swimming and the very low rate of population density (number of individual per litre), filtered hauls of a known volume are required. In shallow water a net for quantitative purpose could not give satisfactory results, because of the differences existing in the vertical distribution. However a metal cylinder provided at one end with a changeable metal screen filters vertical water column in a rather short time. The volume of the water could be calculated from the depths of the water and from the surface of the screen being equal to the opening of the cylinder. A screen of 90—100 $\mu$ meshes catches crustaceans of all stages of development, rotatorians of a certain size (*Keratella quadrata* for instance) as well as larvae of *Dreissena polymorpha*. Some other rotifers are catched also because of their long appendages (*Kellicottia longispina*, *Thriarthra longiseta*) and the material seems to be appropriate to establish population density or for some other quantitative purpose. Therefore if we want to catch forms above the size of 90—100 $\mu$, such sampler gives satisfactory results especially in shallow waters. By uniting three such cylinders

the work is considerably accelerated. (SEBESTYÉN 1960b, 120.) In case of forms of rare occurrence several watercolumns should be filtered. In deep water the height of the column might vary while, in shallow water, a column from bottom to surface could be filtered.

Such samples are rather free from tripton even in Lake Balaton. However very frequently a precipitation is present in the samples causing difficulties in counting. The origin and nature of such substance is not known as yet.

The lack of a hypolimnion in Lake Balaton causes another difficulty at obtaining representative samples. This condition means that members of the plankton community are distributed from bottom to surface. Either a water bottle or the cylinder just described are used, the lowest part of the water column does not enter into the vessel. Thus the material hauled by the cylinder does not represent the entire water column of the lake. However, because the same error invariably occurs, samples are fit for comparison.

Because of the diurnal vertical migration of the plankton crustaceans, especially of *Leptodora*, it seems very likely that samples being taken a f t e r s u n s e t would represent more closely the natural conditions.

Considering what is said above, when planning investigations on population density of plankton crustaceans, it has been intended to take special samples for *Leptodora*. However in the course of the counting it appeared that data might be evaluated for *Leptodora* too as to its population density in our Lake.

In this case more water should be filtered. When counting the individuals, the use of a lower magnification is more satisfactory for *Leptodora* (SEBESTYÉN 1960b, 121.).

The data at hand throw light on the following items:

1. population density of *Leptodora* throughout the year;
2. population density at its maximal development;
3. the ratio between *Leptodora* and the other crustaceans;
4. the horizontal and vertical distribution of *Leptodora*.

Although *Leptodora* is a warm stenothermous form, it occurs continuously from the beginning of the favourable season till November—December. Its population reaches its optimal development toward the end of summer. Both facts observed previously when analysing net hauls, have been verified by the present quantitative studies.

Data concerning 317 individuals of *Leptodora* + 66 899 other plankton crustaceans, excluding the nauplii, caught in 5022 l water are found in *Tables 1—5* and in the *text-table*.

*Table 1.* Data of samples taken in different parts of the year show the following:

1. population of *Leptodora* (the size of which is expressed by the population density = individuals per litre = e/l) increases till the end of summer, after which a decrease takes place;

2. population density of *Leptodora* — compared with that of the food crustaceans — is exceedingly low, 0,1 e/l being the maximal value. This means that in about every 10 l of water but one individual was found;

3. at the time of maximal development the occurrence of *Leptodora* as expressed in percent of the number of all crustaceans (excluding nauplii) is about 0,4%. In the course of the year the ratio is 200—2000 crustaceans to one *Leptodora*.

*Table 1 — 1. táblázat*

| No | d | vl | t °C | Cr (a + j) | L | Cr (a + j) e/l | L e/l | Cr (a + j) L% | Cr' (a + j):L | V |
|---|---|---|---|---|---|---|---|---|---|---|
| 580ab | 1958. I. 10. | 288 | 1 | 629 | — | 2,17 | — | — | — | — |
| 592abc | 1958. II. 14. | 259 | 4—4,5 | 796 | — | 3,05 | — | — | — | — |
| 613ab | 1958. V. 10. | 173 | 16—18 | 4 267 | 2 | 24,63 | 0,011 | 0,04 | 2132 : 1 | 86 |
| 644a | 1958. VII. 1. | 103 | 19—20 | 1 769 | 5 | 17,16 | 0,048 | 0,282 | 352 : 1 | 20 |
| 676ab | 1958. IX. 15. | 173 | 19—20 | 4 333 | 18 | 24,97 | 0,100 | 0,392 | 253 : 1 | 10 |
| 703ab | 1959. XI. 15. | 173 | 5 | 742 | 1 | 4,27 | 0,011 | 0,13 | 741 : 1 | 173 |
| 710ab | 1959. XII. 15. | 187 | 2 | 1 389 | — | 7,41 | — | — | — | — |
| | Total: | 1356 | | 13 925 | 26 | | | | | |

*Table 1.* Data on the population density etc of Leptodora based upon water column samples from the same locality, $A_1$ = open water N off Tihany. N = number of sample; d = time of sampling; vl = volume of water filtered in litre; t = temperature of water in °C; a = adult; j = juvenile; Cr = plankton crustaceans; Cr' = plankton crustaceans other than Leptodora; L = Leptodora; e/l = individuals per litre = population density; Cr L% = quantity of Leptodora in per cent of plankton crustaceans; V = number of litres of water per one Leptodora; abc = parallel samples; összesen = total; átlag érték = average

*1. táblázat.* A Leptodora Kindtii népességsűrűségére stb. vonatkozó adatok hónapok szerint ua. gyűjtőhelyen ($A_1$ = Tihany előtti nyíltvíz) szűrt vízoszlopminták alapján. No = minta száma; d = idő; vl = átszűrt víz mennyisége literekben; t = a víz hőfoka C°; a = kifejlett; j = fiatal; Cr = planktonrákok; Cr' = táplálékrákok; L = Leptodora; e/l = egyedszám literenként = népességsűrűség; Cr L% = Leptodora mennyisége az össz. planktonrákok %-ában; V = hány liter vízben egy Leptodora; abc = mintapárhuzamok.

Dates from June and September in *Table 2.* give an insight into the annual differences in the e/l value in three consecutive years.

*Table 2 — 2. táblázat*

| No | d | vl | t °C | Cr (a + j) | L | Cr (a + j) e/l | L e/l | Cr (a + j) L% | Cr' (a + j):L | V |
|---|---|---|---|---|---|---|---|---|---|---|
| 465 | 1956. VI. 12. | 75 | 20,5—23,7 | 1 024 | 4 | 13,65 | 0,053 | 0,38 | 255 : 1 | 19 |
| 546abc | 1957. VI. 24. | 312 | 25 | 9 029 | 17 | 27,07 | 0,057 | 0,199 | 500 : 1 | 18 |
| 644a | 1958. VII. 1. | 103 | 19—20 | 1 769 | 5 | 17,16 | 0,048 | 0,282 | 352 : 1 | 20 |
| 511a | 1956. IX. 11. | 98 | 22 | 277 | 1 | 2,81 | 0,010 | 0,36 | 276 : 1 | 98 |
| 555abc | 1957. IX. 10. | 260 | 21—23 | 3 175 | 4 | 12,22 | 0,015 | 0,128 | 792 : 1 | 65 |
| 676ab | 1958. IX. 15. | 173 | 19—20 | 4 333 | 18 | 24,97 | 0,100 | 0,392 | 253 : 1 | 9 |
| | Total: | 1021 | | 19 607 | 49 | | | | | |

*Table 2.* Population density of Leptodora etc in three consecutive years based upon June and September samples from the same locality ($A_1$). For other symbols see *Table 1.*

*2. táblázat.* A Leptodora Kindtii népességsűrűségének stb. alakulása három egymást követő évben ugyanazon gyűjtőhelyen ($A_1$) vett júniusi és szeptemberi minták alapján. Jelmagyarázat, mint *1. táblázat*nál.

It appears that the June data are close enough to each other but the September ones are very low and variable, with the exception of № 676 ab. Such peculiar condition might be caused by some environmental factors affecting unfavourable the development of the population. However it might be simply a result of technical deficiency. The e/l value of September 1958 agrees rather well with the September values in *Table 3c*. Nevertheless should be remembered that the few data at our disposal allow but a rough estimate of the differences occuring in the size of the population in different years.

*Table 3* throws light upon the horizontal distribution of *Leptodora*, since the samples originated from various parts of the lake, where the depth of of water is $\geq 3$ m.

*Table 3 — 3. táblázat*

| No | d | gy | vl | t °C | Cr (a + j) | L | Cr (a + j) e/l | L e/l | Cr (a + j) L% | Cr'(a+j):L | V |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | *a*) NE | | | | | | |
| 617 | VI. 30. | $A_0$ | 108 | 18,5 | 1 528 | 2 | 14,14 | 0,018 | 0,13 | 763 : 1 | 54 |
| 621ab | VI. 30. | $B_0$ | 231 | 18—19 | 2 853 | 13 | 12,33 | 0,05 | 0,45 | 218 : 1 | 17 |
| 625ab | VI. 30. | $C_0$ | 248 | 18—19 | 3 413 | 14 | 13,77 | 0,05 | 0,41 | 242 : 1 | 17 |
| 629ab | VI. 30. | $D_0$ | 251 | 18—19 | 4 398 | 16 | 17,50 | 0,06 | 0,36 | 273 : 1 | 15 |
| 633 | VI. 30. | $E_0$ | 124 | 18,5—19 | 3 681 | 14 | 29,55 | 0,11 | 0,38 | 261 : 1 | 8 |
| | Total: | | 962 | | 15 873 | 59 | average | 0,057 | 0,34 | | |
| | | | | | *b*) SW | | | | | | |
| 648ab | VII. 7. | $F_0$ | 187 | 20 | 2 051 | 11 | 10,95 | 0,05 | 0,53 | 185 : 1 | 17 |
| 656ab | VII. 7. | $I_0$ | 216 | 21—22 | 1 644 | 7 | 7,60 | 0,032 | 0,42 | 233 : 1 | 30 |
| 660b | VII. 7. | $J_0$ | 109 | 21,5—22 | 2 024 | 1 | 18,95 | 0,009 | 0,04 | 2023 : 1 | 109 |
| *664a* | *VII. 7.* | $K_0$ | *?* | *21* | *3232* | *36)* | | | | | |
| | Total: | | 512 | | 5 719 | 19 | average | 0,030 | 0,33 | | |
| | | | | | *c*) SW | | | | | | |
| 680 | IX. 29. | $F_0$ | 86,7 | 16 | 2 963 | 15 | 34,12 | 0,173 | 0,506 | 196 : 1 | 6 |
| 702 | X. 1. | $K_0$ | 47,2 | 16—16,5 | 9 215 | 48 | 19,50 | 0,101 | 0,520 | 190 : 1 | 9 |
| 696ab | IX. 30. | $L_0$ | 24,9 | 16—17 | | 31 | | 0,124 | | | |
| 687ab | IX. 30. | $M_0$ | 158,9 | 16 | | 36 | | 0,227 | | | |
| 694 | IX. 30. | Z | 80,9 | ? | | 17 | | 0,211 | | | |
| | Total: | | 1047,5 | | 12 178 | 147 | average | 0,167 | 0,513 | | |

*Table 3.* abc. Data of population density of Leptodora etc. from various parts of the Lake (Depth $\geq 3$ m). NE = North eastern part of the Lake; SW = South western part of the Lake; gy = location of sampling; $A_0$—$E_0$ = sampling places off; Tihany-peninsula toward the NE; $F_0$—$M_0$ = sampling places in the SW part of the Lake off the Tihany peninsula toward SW; Z = ± 1000 m off the mouth of the Zala River. For other symbols see *Table 1.*

*3. abc táblázat.* A Leptodora népességsűrűségére stb. vonatkozó adatok a tó mélységi főtengelyének különböző pontjain vett mintasorozatok alapján. 1958. NE = a tó ÉK-i része; SW = a tó DNy-i része; gy = gyűjtőhely; $A_0$, $B_0$, $C_0$, $D_0$, $E_0$ = az ÉK-i medence gyűjtőhelyei a Tihanyi-félszigettől ÉK-felé haladva; $F_0$, $K_0$, $L_0$, $M_0$ = a DNy-i tórész gyűjtőhelyei a Tihanyi félszigettől DNy-felé haladva; Z = a Zala- folyó torkolata előtt kb. 1000 m-rel; egyéb jelmagyarázat, mint az *1. táblázat*nál.

Part a of the *Table* contains summer data from the north-eastern part of the lake. With the exception of № 617, the population density is similar enough. For the low value of the sample № 617 the location of the sampling place $A_0$ might be responsible, being at the mouth of the Tihanyi-szoros (Tihany-Narrow), the narrowest and deepest part of the Lake where a strong current is frequently observed. The scarce occurrence of *Leptodora* in this sample might find an explanation in the rheophoby of the able swimmer.

There are but few summer samples from the southwestern part of the lake (part *b* of *Table 3)*. The e/l values of two samples are close enough to each other, and agree well with the data of the northern part of the Lake. For the value of sample No 660 no satisfactory explanation could be given except perhaps some technical deficiency in the sampling.

Part *c* of the *table* includes data of the southwestern part of the Lake in early autumn. It is seen

1. that the e/l values are not very afar from each other;
2. that they well exceed the summer values given in part *b*.

In sample № 702 taken 1. October 1958 three *Leptodora* larvae were found, a rather unusual occurrence in this part of the year. We know indeed very little as yet about the earliest part of the life cycle of *Leptodora*.

Data of two sample series taken by pump (50—50 l water from each layer) are included in the *text table* below.

*Text table*

*a)* No 512. 11. IX. 1956. $8^{45} \cdot A_1$ = Open water N off Tihany; depth 3,4 m, smooth water, later on increasing wind and waves.

| depth | Leptodora | Diapha-nosoma | Daphnia | Diap-tomus | Cyclo-pids | nauplius |
|---|---|---|---|---|---|---|
| 0 | — | 2 | 10 | 51 | 72 | 627 |
| 1 | 17 | 41 | 241 | 321 | 363 | 1292 |
| 2 | 1 | 122 | 264 | 546 | 418 | 1032 |
| 2,5 | — | 25 | 30 | 372 | 532 | 547 |

*b)* No 638. 27. IX. 1958. $8^{30}$ br $F_0$ = Open water S off Tihany; depth 3 m. Some breeze and ripples. Temperature of water 16° C in all depths, transparency 63 cm (Secchi).

| Depth m | Leptodora |
|---|---|
| 0 | 1 |
| 1 | — |
| 2 | 15 |
| 2,5 | 6 |

Data of this table throws some light upon the vertical distribution of *Leptodora* under the given time and weather conditions. Most individuals of *Leptodora* were hauled from layers in medium depths. The *Table* gives some data for the vertical distribution of the food crustaceans as well. However from two series of data no further conclusion should be drawn. Pumping itself seems to be a rather rough method for such investigations in a shallow lake.

Concluding from the data given in the *tables* we obtained at least some slight notion about the population density of *Leptodora* in Lake Balaton. This gives encouragement to continue such investigations, in order to learn more about the quantitative occurrence of *Leptodora* in Lake Balaton.

The data throw some ligth upon the numerical relation between *Leptodora* being the top predator of the plankton community and the other crustaceans upon which it preys. (It must be remembered again that the younger generation of copepods: the nauplii and metanauplii are not included in the figures represented by Cr and Cr' in the ratios "Cr': L" and "Cr L%" in the columns of the *Tables*, although young *Leptodora* very likely feeds upon members of these age groups). If we leave out of consideration the fact that food crustaceans are consumed directly by the fish and fishfry too, the matter is greatly simplified. "Cr: L" and "Cr L%" express the proportions between the numerical conditions of the two final and higher levels in the food web of the plankton community, which are — in other words — the two final sections in the pyramid of numbers (ELTON) in the community.

It has been emphasized earlier that — even when leaving out the bacteriophageous and detritophageous members of the community — the central part of the food web is very intricate. This is because here the two main principles in feeding — size and trophic level — are realized side by side and interwoven. (SEBESTYÉN 1960, 68). For this reason the food relation of the plankton-community can hardly be expressed in its whole extension in a pyramid.

Further studies on *Leptodora* from an ecological point of view, should deal with the following:

1. Continuation of the study of population density of *Leptodora* and other plankton crustaceans all over the lake with an improved sampler; more samples have to be taken especially after sunset.
2. The composition of population according to age throughout the year; population dynamics of *Leptodora*:
3. Rate of natural death; parasites and the loss caused by them.
4. Establishment of the volume of *Leptodora* of different ages by direct measurement;
5. Variation of the biomass of *Leptodora* population throughout the season;
6. Part of the population consumed by fish and fry;
7. Finally a study of the material connection between plankton and nekton according to quality and quantity.

These items are needed in order to learn something of the role of *Leptodora* in the circulation of matter in Lake Balaton, a shallow lake where the trophogenic and tropholytic activities to be displayed in the same layer and a hypolimnion is wanting.

**Summary**

Using a newly constructed simple sampler by which in a shallow water entire watercolumns can be filtered, data gained by filtering 5022 l water altogether from different parts of the lake — refer to 317 individuals of *Leptodora* and 66 899 other crustaceans (nauplii and metanauplii not included in this number).

Evaluating these data it could be established that population of *Leptodora* from the beginning of the season grows toward the end of summer and then decreases. Population density at its peak is only about 0,1 e/l, which represents but 0,4% of all plankton crustaceans. In two sample series pumped from different depths most individuals were hauled from the middle layers.

*Leptodora* is distributed all over the Lake, highest values originating from samples taken both at the Bay off Keszthely and next to the mouth of the Zala River. In the sample taken from the former locality 1. October three larvae of *Leptodora* were found.

The proportion between the top predator and its food crustaceans varies between 200 and 2000 throughout the year, and represents at the same time the numerical relation of the two final sections of the pyramid of numbers within the plankton community, both in trophical sense and size. The lower parts of the food web of the plankton in Lake Balaton — excluding the basic level — is very intricate and can not be expressed as a pyramid.

It has been pointed out that if we endeavour to learn more of the role of *Leptodora* in the circulation of substances in the Lake both in the qualitative and quantitative senses, there are many problems still to be faced.

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## MENNYISÉGI PLANKTONTANULMÁNYOK A BALATONON X. NÉHÁNY ADAT A *LEPTODORA KINDTII* FOCKE NÉPESSÉGSŰRŰSÉGÉRŐL

*Sebestyén Olga*


### Összefoglalás

90—100 $\mu$ lyukbőségű bronzszitán átszűrt vertikális vízoszlop-minták adataiból (45 minta, ebből 2 *Leptodorára* negatív): 5022 l víz; 67 216 planktonrák (naupliuszok nélkül) — ebből 317 *Leptodora* — némileg tájékozódhatunk a *Leptodora Kindtii* népesség sűrűségéről a Balatonon.

Ugyanazon gyűjtőhelyen az év különböző szakaszaiban vett minták adatai szerint a *Leptodora* népességsűrűsége, a megjelenéstől növekedve, szeptemberben ér el magas értéket. Ekkor is csupán mintegy 10 liternyi vízre esik egyetlen egyed, és egy *Leptodorára* kb. 250 táplálékrák (naupliusz nélkül). *(1 táblázat)*

Egymást követő három évben a júniusi e/l adatok egyezése kielégítő, a szeptemberi adatoké azonban csak egy esetben felel meg a tó más részein vett szeptemberi adatoknak. Az eltérést (az állomány csökkenése júniustól—szeptemberig?) külső környezeti körülmények kedvezőtlen alakulásával lehetne kapcsolatba hozni, de technikai hiányokról (az átszűrt víz kevés volta?) is lehet szó *(2. táblázat)*.

A tó mélységi főtengelyében vett minták adataiból kitűnik, hogy az ÉK-i medence e/l adatainak egyezése kielégítő, a Tihanyi-szoros közelében $A_0$ gyűjtőhelyen vett 617. sz. minta kivételével, melynek *Leptodora*-szegénysége talán a szorosban levő áramlással és a jól úszó planktonrák reofobiájával(?) magyarázható *(3a táblázat)*.

A DNy-i medence kevés nyári L e/l adata között az ÉK-i medence adataihoz hasonló csak egy van. *(3b táblázat)*

A DNy-i medence nyári *(3b táblázat)* és őszi értékeit *(3c táblázat)* összehasonlítva, kitűnik a szeptemberi értékek magassága, ami azt jelenti, hogy az állomány lényegesen

növekedett. Feltűnő a Zala-torkolat közelében sekély vízben ($Z_0$) és a Keszthelyi-öböl közepén ($M_0$) vett minta *Leptodorá*ban való gazdasága, mely értékek eddigelé a legmagasabb e/l értékek a *Leptodorá*ra.

Néhány szivattyúval vett minta adatai rámutatnak a vertikális elhelyezkedésre is, az adott gyűjtési körülmények között *(szövegközti táblázat* 135. o.).

Minthogy az átvizsgált mintákban a planktonrákok — az egy csoportban számlált Cyclopidák és a naupliusz-lárvák kivételével — fajonként voltak számbavéve, az adatokból kitűnik a ragadozó *Leptodora* és a táplálékrákok számbeli viszonya is. (A táblázatokban Cr: L; Cr L%). (Bár a Copepodák naupliuszait is számláltam, most nem vagyok tekintettel arra, hogy a fiatal *Leptodora*, nagyságrendjének megfelelően, legfeljebb fiatal Copepoda lárvákat, így naupliuszokat is fogdoshat). Ez az arány tulajdonképpen a plankton táplálékhálózatában a két végső tag számbeli összefüggésére utal, ha eltekintünk attól, hogy a *Leptodora* táplálékrákjait halak közvetlenül is fogyasztják. Ez a szakasz — annak következtében, hogy nincs adatunk arra, hogy a Leptodora planktonrákokon kívül más planktonállattal is táplálkozna — a két utolsó lépcső trofikus és egyúttal nagyságrendi összefüggését rendkívül leegyszerűsíti, és fenti megvilágításban a s z á m o k p i r a m i s á n a k v é g s ő é r t é k e i t képviseli. A tavi plankton táplálkozási összefüggéseit illetően, a kezdeti és végső lépcsőtől eltekintve, a trofikus szint mellett a nagyságrendi fokozat, mondhatni, ugyanolyan súllyal jut kifejezésre. Ez más szóval azt jelenti, hogy ha a detrítusz- és baktériumfalástól eltekintünk, a planktonalgáktól a *Leptodorá*ig vezető táplálkozási kapcsolat közbülső szakasza, hogy úgy mondjam, piramisszerűen aligha fejezhető ki. Ez a közbülső szakasz, mint már máshol is kifejeztem, különösen a Cyclopidák szűrő-ragadozó táplálékszerzése következtében válik rendkívül bonyolult hálózattá (vö. SEBESTYÉN 1960, 1960a,).

Szerző dolgozatában rámutat arra is, hogy a hipolimnion nélküli sekély Balatonon a tavi anyagforgalom megismerésére a plankton csúcsragadozójára vonatkozóan milyen további feladatok várnak megoldásra.